CONDITIONS FOR GROWTH OF CHONDRULES AND THEIR PRECURSORS. C. E. KenKnight, Minneapolis MN, kenk@physics.spa.umn.edu

Abundance values for whole meteorites were shown in the 1970s to be dominated by the volatility of the elements. Yet Gooding et al. [1] found that mean abundances for chondrules are not appreciably affected by volatility, so by default the losses from chondrites involved small grains. The growth process for chondrules must have included formation of low-degree melts because element abundances have been affected in ways more or less familiar from geochemistry. The melt was more likely to be corroded away during growth because (1) it was less refractory than core crystals such as forsterite and (2) it often formed a surface layer and vein connections to that layer. New plots of published data from 17 chondrules of Chainpur (LL3.4) suggest that (1) fractionation (loss) of metal was intimately linked to transport of sulfur due to a Fe-S-O melt, (2) abundances of the volatiles Na, K, Fe, and Ga changed rapidly near the onset of lithophile refractory (LithRef) increases, (3) growth of LithRefs depended on gaseous corrosion of a Ca, Al, Ti-rich nonrefractory melt, and (4) growth of LithRefs competed with Mg-rich chondrules.

Grossman et al. [2,3] reported on 36 chondrules from Chainpur, giving abundances for 18 elements measured by instrumental neutron activation analysis. They gave results for 17 chondrules, which are shown in Figs. 1–8. For each element I divided the measured abundance by "means," the average abundance for LL meteorites (where available in [4]) or by the whole rock abundance [2]. The 17 chondrules were put in order of increasing Ir content, a measure of metal formation. To avoid clutter and to help reveal trends, I averaged the normalized abundances over three chondrules. Similarly for Figs. 5–8, I ordered by Mn, omitting the two chondrules with highest Ir. The siderophiles Co, Ni, Au (Fig. 1) are nearly proportional to Ir content. They are mostly in a single-phase, common metal. At high Ir the fraction of Ir and Au falls, the result of their being also in nuggets of a noble metal with the platinum group elements. Note that Mn decreases steadily as Ir increases in Fig. 2. The element S is not measured by neutron activation, but Se may be taken as a surrogate because Se occurs only in FeS. The Mn-ordered figures have a low system temperature T at the right. The chalcophiles Se and As, as well as Zn, increase with metal and T (to the left) in Figs. 5 and 6. The association of metal and sulfides in chondrules is common [5]; these data suggest that the association is causal. Since the volatility of sulfides is so high in a cosmic gas, the chondrule-forming environment must have had a high dust-to-gas ratio. According to [6], raising the dust component by 1000 times raises the stability of sulfides to about the ternary eutectic of the system Fe-S-O, 915°C [5]. At slightly higher temperatures a liquid (often two immiscible liquids) will be present (briefly) at or near the surface of precursors. In such a liquid, diffusion to a surface can be much more rapid than diffusion through a solid. Also surface tension of the liquid helps to restructure low-density dust agglomerates. Evidently the metal-sulfide liquid enabled much metal to be isolated from precursors before silicate aggregates became chondrules.

In Figs. 4 and 8 we see that Mg, Al, Sc, V, and Sm are above the whole-rock average for any Ir or Mn amount (Ca had poor accuracy). As emphasized in [1], all the LithRefs are enriched in the chondrules. Since LithRefs vary widely in volatility and in their mineral siting but do vary in whole-rock abundances between the chondrite groups, the making of silicate chondrules had a chemical control factor. Formation of a silicate melt phase stabilized by volatiles tended to be exposed at the surface of chondrule precursors (smaller objects) where a hot, corrosive nebular gas could attack it. Like metal absent at low Ir in Fig. 1, the first silicate melt was mostly removed, ending as black matrix. Rapid diffusion in the melt helped move volatiles to the surface. Metal and sulfide losses were less as an increasing T could furnish both metal-sulfide and silicate first-melts (Fig. 5 and 6). LithRefs increase with T (to left in Fig. 8). Near Mn = mean LL abundance, all volatiles fall (Fig. 6); Mg reaches a maximum there and then decreases. Their absence suggests that a third melt giving excess LithRefs then becomes important. Mg is special among LithRefs, in that it tends to grow and be retained in the refractory olivine and pyroxene major phases. Mg mostly avoids the hot gases and rather furnishes a refractory growth surface for melt. Semarkona gives similar results.

References: [1] Gooding J. L. et al. (1980) *EPSL, 50,* 171–180. [2] Grossman J. N. (1979) *LPS X,* 464–466. [3] Grossman J. N. andWasson J. T. (1982) *GCA, 46,* 1081–1099. [4] *Meteorites and the Early Solar System,* Appendix 3 (1988). [5] Haggerty S. E. and McMahon B. M. (1979) *Proc. LPSC 10th,* 851–870. [6] Wood J. A. and Hashimoto A. (1993) *GCA, 57,* 2377–2388.

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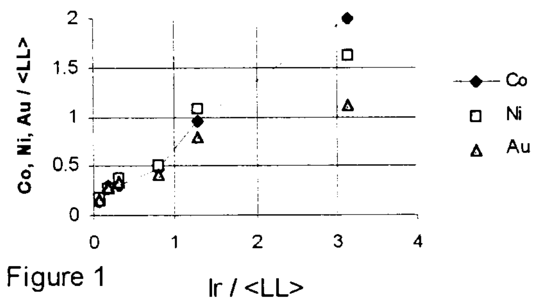
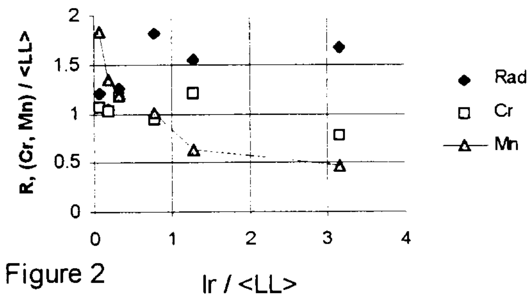


Figure 1



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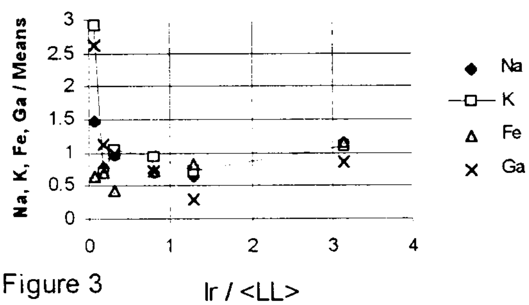

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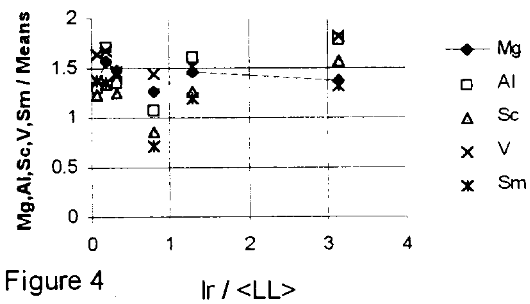

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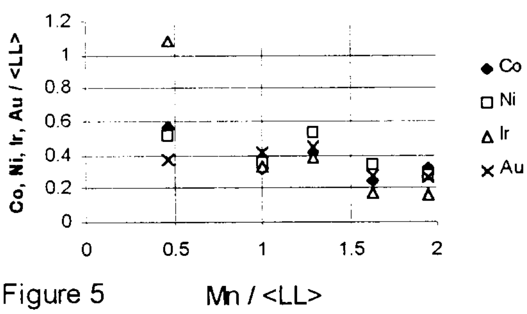

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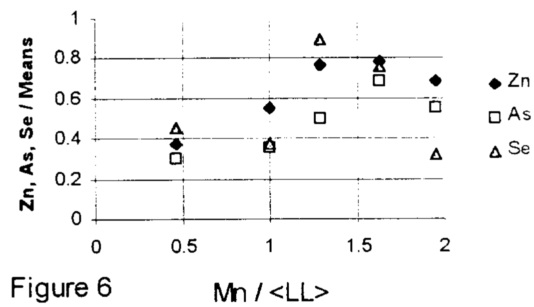

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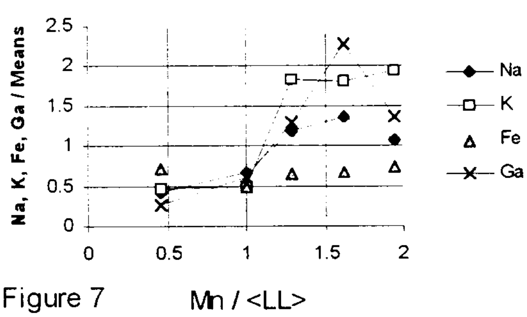

Figure 7

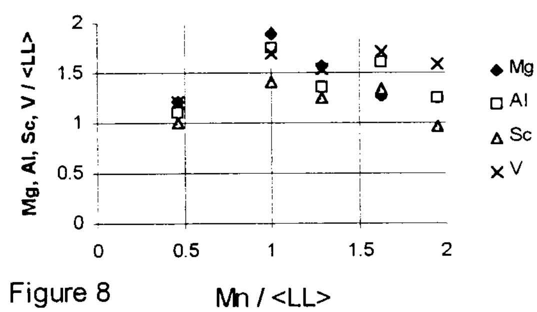

Figure 8